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Review

The role of multimedia in surgical skills training and assessment☆

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ABSTRACT

Introduction: Multimedia is an educational resource that can be used to supplement surgical skills training. The aim of this review was to determine the role of multimedia in surgical training and assessment by performing a systematic review of the literature.

Methods: A systematic review for published articles was conducted on the following databases: PubMed/MEDLINE (1992 to November 2014), SCOPUS (1992 to November 2014) and EMBASE (1992 to November 2014). For each study the educational content, study design, surgical skill assessed and outcomes were recorded. A standard data extraction form was created to ensure systematic retrieval of relevant information.

Results: 21 studies were included; 14 randomized controlled trials (RCTs) and 7 non-randomized controlled trials (Non-RCTs). Technical skills were assessed in 7 RCTs and 3 non-RCTs; cognitive skills were assessed in 9 RCTs and 4 non-RCTs. In controlled studies, multimedia was associated with significant improvement in technical skills (4 studies; 4 RCTs) and cognitive skills (7 studies; 6 RCTs). In two studies multimedia was inferior in comparison to conventional teaching. Evaluation of multimedia (9 studies) demonstrated strongly favourable results.

Conclusions: This review suggests that multimedia effectively facilitates both technical and cognitive skills acquisition and is well accepted as an educational resource.

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Introduction

Work patterns in the UK have changed with increasing reliance on shift systems and a reduction in training hours (as specified by the European Working Time Directive (EWTD)). Prior to the Calman report in 1993 a surgical trainee would have expected to work over 30,000 hours before becoming a consultant.[1] With the impact of changing working practices and the recent Modernising Medical Careers (MMC) reforms, training hours have now fallen to below 6000 hours.[2] The current model of seamless training from graduate to consultant status further reduces the period of generic training.

Surgical trainees are now also increasingly removed from normal working hours in which the majority of traditional operative experience is gained.[3] Increasing consultant accountability for patient safety, and greater diversity of available techniques within each speciality has also led to a reduction in training opportunities.[4]

The above mentioned changes have led to a rapid development of educational models designed to counter the impact of reduction in training time to attain surgical skills.[5] The most notable of these models has been simulation,[6] focussing on technical performance. Although these platforms demonstrate educational benefit, they can be cost intensive and bonded to schedules and location.[7]

Multimedia technology is an educational resource that can augment surgical skills training. Multimedia is media that uses a combination of different content forms, and can be defined as the integration of text, audio, images, animation, video, and interactivity content forms.[8] The use of media stimulates visual and auditory receptors, improving the understanding and transfer of complex temporal and spatial events.

The evidence base for multimedia has also grown and has been shown to be effective in disciplines including radiological education and surgical pathology.[9,10] The use of multimedia technologies has also been evaluated in areas of communication with positive results particularly with regards to pre-operative counselling, consenting[11] and patient comprehension.[11,12]

The advantages of multimedia include increased efficiency[13] and allowance for practice in a learner-centred environment with flexibility in time and location[14] and the potential to personalise instruction to individual needs.[14] This can be achieved by delivery of multimedia tools as standalone packages (DVD) via the internet ("e-learning). Additionally, increasing departmental budget constraints for courses may force trainees to "pick and choose" only mandatory courses. Travelling commitments in terms of time and cost may further deter trainees from attending courses. Multimedia could potentially solve some of these issues. Multimedia would therefore appear to be a suitable medium for surgical skills training.

There has been increasing backing from educators for implementation of innovative teaching methods that make use of multimedia.[15] There is also some evidence to suggest that surgical trainees in the UK are dissatisfied with traditional teaching methods[16] while there appears to be a growing interest with online multimedia augmented instruction.[17] The aim of this systematic review was to determine the extent to which the 'role of multimedia in surgical training and assessment' has been researched and to summarise the findings.

Materials and methods

This systematic review was carried out in accordance to the PRISMA statement[18] to aid transparent and complete reporting of our study.

A detailed electronic search was carried out on the following databases: PubMed/MEDLINE (1992 to November 2014), SCOPUS (1992 to November 2014) and EMBASE (1992 to November 2014). The following search terms were used: (Multimedia OR "computer learning" OR "internet learning") AND (surgery OR procedure) AND (teaching OR assessment OR education OR skills). One reviewer (US) independently performed the database search. The full text of relevant articles was retrieved and reviewed.

All original articles in the English language literature that evaluated the role of multimedia in the teaching, training or assessment of surgical procedures or surgical skills involving medical students, post-graduate surgical trainees and practising surgeons were included. All articles deemed clearly relevant were examined in full text. To be included, studies had to include the use of multimedia in surgical or skills/interventional procedures. All study types were considered eligible. Articles focussing primarily on 'simulation', 'virtual reality training' or teaching non-procedural aspects of surgery (i.e. anatomy, pathology, interpretation of diagnostic test); articles relating to dental surgery; and articles relating to patient education, consent or epidemiology were excluded. Articles evaluating participants of non-surgical backgrounds (i.e. physicians) were excluded. Non-English Language articles, articles published only in abstract form, reviews, opinion papers, single case reports and commentaries were also excluded.

One reviewer (US) independently reviewed all titles and available abstracts in the databases and included articles meeting with the eligibility criteria. Full text articles were then retrieved via online access or in print form. A standard data extraction form was created to ensure systematic retrieval of the following information: Year, Country, Discipline, Subject/skill assessed, Study type, Control & type, Population & Number, Multimedia description, Delivery method, Instructional Methods used, Study format, Method(s) of Assessment, Timing of assessment, Summary of main results/outcomes, Critical Appraisal, Risk of bias and Follow-up.

The main outcome parameters/measures assessed in this review were improvements in technical and cognitive surgical skills.

All data were initially collected by one reviewer (US). A second reviewer (CS) separately reviewed and extracted all data independently. Any disagreement over data extraction was discussed and a consensus reached. As a result of the significant variation in the heterogeneity of study methods and outcomes, no data synthesis or meta-analysis could be performed.

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Results

Figure 1 is a flowchart demonstrating the process of study identification, screening and assessment of eligibility and inclusion of articles in the preferred reporting items for systematic reviews.[18] Table 1 shows in detail the main characteristics of the included studies.

The majority of studies (17/21; 81%) recruited a single participant group and were single centre studies (76%) Just

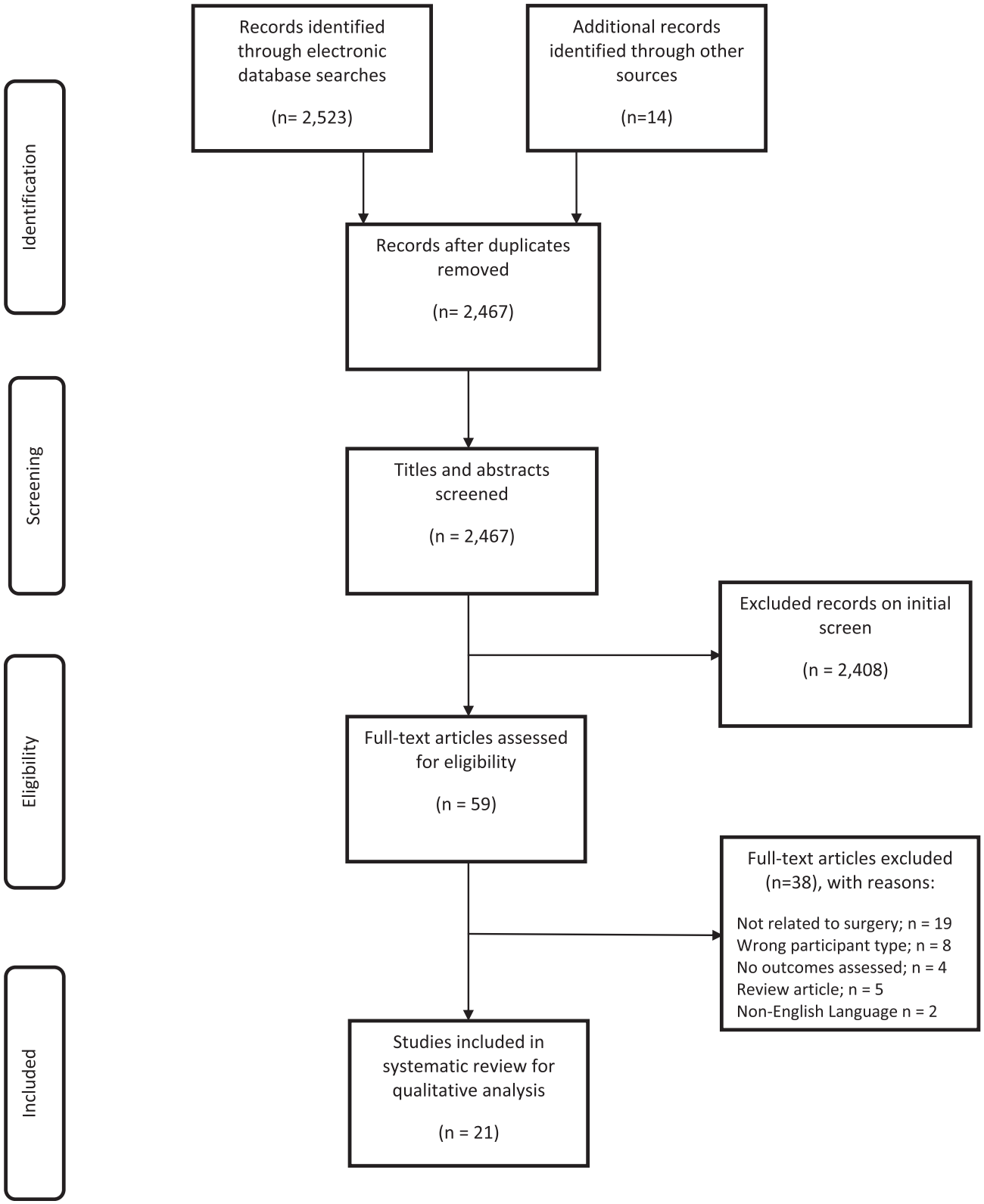

Fig. 1 – Flowchart showing selection of articles for review according to PRISMA guidelines.

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Table 1 – Overview of the main characteristics of included studies.

First author, year	Specialty/ discipline	Skill or procedure	Skills assessed	Study design	Participants	Method of delivery/ multimedia description	Study number
Summers, 1999	Basic surgical skills	Knot tying and suturing techniques	Technical & cognitive	RCT, single centre	Medical students	Computer based training (CBT)	58 (didactic group – 17; videotape group – 20; CBT group – 21)
Rosser, 2000	Laparoscopic skills	Knowledge of laparoscopic skills	Cognitive	Non-RCT, multi-centre	Residents and surgeons	CD-ROM presented from data projector *Description*: "The Art of Laparoscopic Suturing"	201
Ramshaw, 2001	General surgery	Laparoscopic general surgical procedures	Cognitive	Non RCT, single centre	Residents	CD-ROM	41
Prinz, 2005	Ophthalmology	Cataract/glaucoma surgery	Cognitive	RCT Post-test only, single centre	Medical students	DVD *Description*: Ophthalmic Operation Vienna	172 (3D group – 90; control group – 82)
Friedl, 2006	Cardiac surgery	Aortic Valve Replacement	Cognitive	RCT, single centre	Medical Students	Delivery: Internet-based module Aortic Valve Replacement Multimedia Module	126 (Multimedia group – 69; Print medium – 57)
Xeroulis, 2006	Basic surgical skills	Suturing and knot-typing	Technical	RCT, single centre	Medical students	Computer-based video instruction (CBVI)	60 CBVI group – 15, concurrent feedback group – 15; Summary feedback group – 15; control group – 15)
Jowett, 2007	Basic surgical skills	One handed knot-typing	Technical	RCT, single centre	Medical students	Delivery: Computer-based video training (CBVT): run on laptop	30 (cease practice group – 20; additional practice group – 10)
Lee, 2007	Paediatrics (specific procedure)	Paediatric intraosseous (IO) insertion	Cognitive	RCT, single centre	Medical students	Instructional DVD for IO insertion	36 (DVD group – 18; teaching session group – 18)
Luker, 2008	Plastic surgery	Flexor tendon repair	Cognitive	Non-RCT Pre-post test; single centre	Residents	Delivery: Multimedia instructional video	9
Nousiainen, 2008	Basic surgical skills	Suture/knot-tying technique	Technical	RCT; single centre	Medical students	Computer-based video instruction (CBVI)	24 (CBVI only – 8; CBVI with self-directed study – 8; CBVI and expert instruction – 8)
Perfeito, 2008	Thoracic (specific procedure)	Pleural drainage technique	Cognitive	RCT; single centre	Medical students	CD-ROM: on departmental computer	35 (CD-ROM group – 18; traditional class group – 17)
Jensen, 2008	Basic surgical skills	Skin closure and bowel anastomosis	Technical	Non RCT; single centre	Residents	Computer based program in Skills Lab	45
Rogers, 2008	Basic surgical skills	Two-handed square knot	Technical	RCT; single centre	Medical students and interns	CAL (Computer assisted learning)	82 (CAL – 40; Lecture and Feedback seminar group – 42)
Ricks, 2008	Paediatric (specific procedure)	Paediatric emergency procedures	Cognitive	RCT; single centre	Medical students	CAL (Computer assisted learning) Hospital Information Services	23 (CAL group – 13; control – 10)
Sarker, 2009	General surgery	Laparoscopic Cholecystectomy	Cognitive	Non-RCT; multi centre	Trainee surgeons	Delivery: Computer-based program Description: LapSkill	20

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Pape-Koehler, 2013	General surgery	Laparoscopic Cholecystectomy	Technical	2 × 2 factorial RCT; multi centre	Medical students and fellows	Multimedia-based interactive platform (www.webope.de): Webop chapter: Laparoscopic Cholecystectomy on Pelvi-Trainer Internet-based on personal computer (PC)	70 (Multimedia-based training – 18; practical training – 17; combination training using with multimedia-based + practical training – 18; No training – 17)
Hearty, 2013	Orthopaedic surgery	Closed reduction and pinning of paediatric supracondylar fractures	Technical	Crossover RCT; multi centre	Residents	Computer enhanced visual learning (CEVL) module	28 (CEVL – 14; control group – 14)

over half of the studies (11/21) enabled self-directed learning using multimedia platforms. However, only 3 of these studies (27%) allowed for learning in unstructured settings, in participant's own time. A variety of delivery methods of multimedia was used across the studies (Fig. 2).

Table 2 provides a summary of the main results. Skills-based platforms are designed to teach and assess specific basic surgical skills, while procedural-based platforms were used to teach and assess surgical operations or procedures related to aspects of surgery. Overall, multimedia was developed in 7 (33%) skills-based and 14 (67%) operative/procedural-related themes. Nine multimedia platforms were developed in the following surgical disciplines: general surgery (3), plastic surgery (2), and 1 in each of orthopaedics, ophthalmology, cardiac and urology. Another seven studies focussed on basic surgical skills and five other studies on specific procedural related aspects of surgery.

There were 14 randomized controlled trials (RCTs) and 7 non-randomized controlled trials (non-RCTs). Of the 14 RCTs, five studies evaluated skills-based platforms and 9 studies evaluated procedural-based platforms. 2 (out of 7) Non-RCTs evaluated skills-based programs; 5 non-RCTs evaluated procedural-based platforms. In the RCTs, 8/14 (57%) had a pre-post test study design; 6 (43%) had a post-test only study design. In the non-RCTs, 4/7 had a pre-post test study design and 3 had a post-test only study design.

In 4/14 (29%) RCTs more than one control group was used. Overall, 20 control groups were used in the RCTs and they included traditional didactic expert instruction/lectures (7), print medium (3), media-comparative (4), practice training (3) and non-intervention (3). Concurrent control groups were used in 4 non-RCTs and included traditional live instruction (2), group with previous experience with intervention (1) (CEVL)[19] and no intervention (1).

In 19 studies (90%), one skill was assessed. In the other two studies[13,20] which were RCTs, both technical and cognitive skills were assessed. Technical skills were assessed in 6 of 7 skills-based programs and 4 of 14 procedural-based programs, while cognitive skills were assessed in 2 of 7 skills-based platforms and 11 of 14 procedural-based platforms. Technical skills were assessed in 7 RCTs and 3 non-RCTs; cognitive skills were assessed in 9 RCTs and 4 non-RCTs.

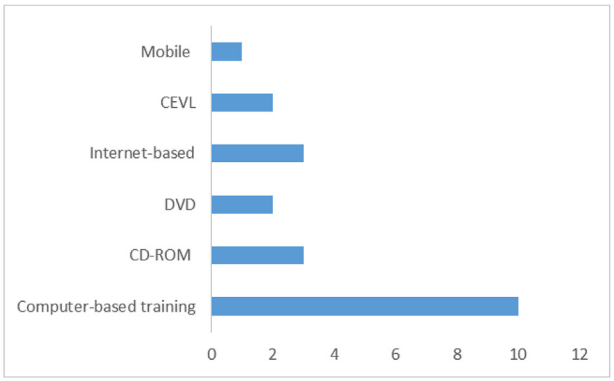

Fig. 2 – Delivery method for multimedia platforms. Raw data: Mobile: 1, CEVL: 2, Internet-based: 3, DVD: 2, CD-ROM: 3, Computer-based training: 10

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Table 2 – Summary of main results and outcome data of the included studies.

Author	Instructional methods	Study format	Method(s) of assessment	Timing of assessment	Summary of main results	Critical appraisal	Risk of bias	Retention test
Summers et al.	3 groups: Traditional didactic skills instruction Videotape: expert instructor led Multimedia computer based training (CBT) program: expert instructor present	Instruction (all participants): 60 min Skill station: Performed on pig feet 90 min (knot-typing) + 120 min (suturing) for all groups	Written 50 item MCQ Structured checklist and specific objectives/ anchored rating form Performance quotient score = derived from multiple observations	Baseline pre-instruction MCQ and skills assessment Immediate post-group intervention MCQ and skills assessment	Videotape and CBT groups demonstrated significantly higher enhancement of technical skills Following intervention, didactic group achieved significantly better scores in MCQ compared to other groups At 1 month follow-up: performance only improvement in CBT group	Learning effect – pre-instruction Expert instructors present for CBT group – bias Non-validated assessments Evaluators not experts Not blinded for pre and post group assessments	High	1 month
Rosser et al.	Two methods: 3 groups underwent CD-ROM tutorial (US surgeons; Greek surgeons; US residents) 1 group underwent stand-up tutorial (US trained surgeons)	2-day course in classroom setting Length of tutorials not stated.	51-item multiple choice test: germane to the educational material.	Pre and post instruction (day 1)	Mean increase in scores between pre-post test was significant ($p < 0.001$) and similar magnitude for each group	Non-RCT Selection bias Heterogenous group Minimal description of multimedia tool Non validated assessment tool CR-ROM learning not self-directed		None
Ramshaw et al.	Self-directed learning using multimedia programs (same for all participants)	Self-directed learning over 3 month period. Only available viewing in resident conference room	Self-assessment evaluation survey using 10-point scale of knowledge and comfort level	Post-study period (within 3 months)	Subjective knowledge level increased from 6.0 to 8.7 and comfort level increased from 5.3 to 8.1	Non RCT Selection bias Small sample size Non validated assessment tool		None
Prinz et al.	Multimedia DVD for groups 2 Groups: Surgeons "view" of procedure 3D animated group: surgeons "view" and animated sequence	Based during 8-week block. Presentation viewed in lecture during classes. Presentations each 10 min	19 multiple choice questions Evaluation survey (four level ordinal scale) for both	Immediately post presentation	3D group outperformed control in both topographical and theoretical understanding ($p < 0.001$) Interactive multimedia tools evaluated as important/valuable supplement to conventional teaching	No baseline score (pre-test); both groups may not be comparable Non validated assessment tool	Low	None

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Friedl et al.	Self-directed multimedia learning group Self-directed Print Medium group: 62 page structured booklet	1 day in Multimedia laboratory to study material (both groups): unlimited time Following day: operating room (OR)	20 item multiple choice questions Assessment of initial motivation (QCM) and confidence in use of computers (CUC) 28 tasks/open questions to assess procedural understanding in OR Validated questionnaire: HILVE to evaluate teaching	MCQ Pre and post tool (immediately)	Multimedia group slightly more motivated than print group in the QCM test There were no significant differences in the multiple-choice pre-test and post-test responses Multimedia group needed significantly less study time compared to print group Performance in the operating room was significantly improved in the multimedia group when compared with the print group	Non validated MCQ assessment tool Immediate assessment ?preparation prior to course Target group medical students, not residents/ surgical trainees	High	None
Xeroulis et al.	4 groups: Self-study with computer-based video instruction (CBVI) Expert feedback during practice trials (concurrent feedback) Expert feedback after practice trials (summary feedback) No intervention (control)	Participants viewed an instructional video then pre-tested on interrupted knots with 3 square throws All participants: 19 trials of practice (1 h), in assigned training condition	Expert assessment Global Rating Scale (GRS): tissue handling, efficient hand movements, instrument use, flow, and overall performance Each component marked on 5-point scale Hand motion efficiency: Imperial College Surgical Assessment Device (ICSAD)	19th practice used immediate post-test 1 month	The CBVI, concurrent feedback and summary feedback methods were equally effective initially for instruction of this basic technical skill and displayed better performance compared to control At retention only CBVI and summary feedback groups retained superior suturing and knot-tying performance versus control	Method of randomisation stated or allocation concealment Groups numbers or characteristics stated Simple task: multiple practice attempts prior to post-test	High	1 Month
Jowett et al.	CBVT module on double 1-handed knot tying (all participants) 2 experimental groups: Cease practice Additional practice Practice blocks on identical three quarter inch dowel model for both groups.	Performed in skills laboratory Practice period (intervals of 6 and 3 min) to self-assessed proficiency Additional practice group (4 extra 3 min practice blocks)	15 item general self-efficacy scale Self-assessment questionnaire on test performance: 4-item global rating scale (to cease or additional practice) Pre, post and retention test of video captured material using objective rating scale	Immediately	Performance improvements in all groups ($p < 0.05$) No differences in 2 groups.	Small sample size ?Target population – effect size ?subjective assessments of self-assessed proficiency – bias Single surgical skill assessed	High	1 week post-retention
Lee et al.	2 groups Interventional group: VD-based teaching medium Control Group: Traditional, four-step, face-to-face expert teaching Paediatric training mannequin	2 weeks prior to study, all candidates given theory notes on procedure Intervention group: 10 min DVD session, then 10 min practice session with mannequin	Standardized checklist of critical steps for successful task completion (out of 10) Modified Likert score on teaching experience	Checklist completed at time of task completion	The interventional group significantly higher mean score compared to control teaching group No difference in the candidates' perception on satisfaction, anxiety and confidence level about teaching experience.	Small sample size Short exposure study time Non-validated assessments No baseline assessment to compare groups Learning bias from pre-training	Unclear	None

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Table 2 – (*continued*)

Author	Instructional methods	Study format	Method(s) of assessment	Timing of assessment	Summary of main results	Critical appraisal	Risk of bias	Retention test
Luker et al.	Intervention: Multimedia instruction video – self-directed Traditional learning (control group)	Skills lab setting: Performance of repair in 3 sessions Traditional learning session after 1st repair Instruction using multimedia after 2nd repair	Talk aloud protocol assessment tool: understanding of procedure and decision making points	Immediately following each repair	All residents showed improvement in knowledge and decision making after traditional learning All residents showed significant increase in knowledge and decision making after multimedia	Non-randomised Small sample size Residents of varying surgical experience Non validated assessment tool Learning effect bias after 2 sessions		None
Nousiainen et al.	3 groups: Group 1: View six-phase version of video. Group 2: Self-directed interactive video learning during practice events Group 3: video and expert instruction (after 9th suture attempt)	All participants: 7-min training session: an expert-narrated, instructional video on instrument knot-tying Practice duration: 18 trials 30–40 min	Computer based assessment: Imperial College Surgical Assessment Device (ICSAD) Performance based assessment: videotaped performance assessed using a global rating scale by two blinded experts	Pre-test immediately after training session. Post-test immediately after practice session Retention test: 4 weeks	All three groups demonstrated significant improvements on both measures between the pre- and post-tests as well as between pre-tests and retention-tests ($p < 0.01$), no significant differences were detected among the three groups	Small sample size Subjective bias on plateau of performance Multiple practice sessions Learning bias/practice effect with retention test Single basic technical skill?	Low	4 week retention test on suturing
Perfeito et al.	2 groups: Group 1: Self-directed learning with multimedia program Group 2: Traditional Theoretical class	Group 1: 90 min self-directed learning in computer room Group 2: 90 min theoretical class	Objective theoretical test: 36 MCQs and 7 descriptive questions 2 subjective written assessments (for Group 1)	Post-test immediately following intervention Subjective assessments: immediately after program and more detailed again	No difference in MCQs, but there was a significant difference in descriptive results for Group 1 compared to Group 2 Subjective evaluation very positive	Small sample size ?no description on random assignment Non-validated assessment tool No baseline test to compare groups	Unclear	None
Jensen et al.	Laboratory based instruction session Narrated digital video on skin excision/closure & hand-sewn bowel anastomosis Porcine abdominal skin and harvested porcine small bowel	Multimedia-based cognitive pre-training Self-directed practice: 2 h Faculty supervised practice: 2 h Self directed practice 2 h practice session in skills lab 65-min objective assessment	Digital video recording for task performance: modified OSATS score	3 objective assessments: pre-training on 1st attempt and post-training performed on last assessment Study survey assessment	Significant differences were seen between pre- and post-test for 5 of 6 objective measures Significant improvements were seen in both time to completion and OSATS global ratings score for both procedures	Small sample size Selection bias ?bias of faculty supervision or pre-training for benefits – multimedia pre-training not compared to practice, just as adjunct Immediate outcomes		None

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Rogers et al.	2 Groups: Computer-assisted learning (CAL): 12 step multimedia program – self directed LFS Session (CAL with a lecture and feedback seminar) Knot tying board and sutures	1 h with CAL or LFS session End of session: all participants instructed to 2-handed knot	Rating scale (out of 24) to assess quality of knot typing: videotaped rater evaluation	Not specified (videotaped assessment)	CAL group had significantly lower quality of performance compared to LFS group No difference in proportion of participants able to tie a square knot or average time to perform task	Trainees received feedback whilst practising skill Non-validated rating scale assessment	Unclear	None
Ricks et al.	2 groups: CAL group: self-directed web-based computerised tutorials on paediatric emergency procedures Control group: non-interventional	CAL group review all tutorials: 45 min. Reviewed in hospital training centre. Followed by assessment. Control group: assessment test followed by tutorials	20-item multiple choice examination	Immediately post tutorials (for CAL group)	Intervention groups had significantly higher average examination score	Small sample size No baseline test Participants notified about required procedural knowledge 2 weeks prior to study	High	None
Sarker et al.	Self-directed, self-appraisal learning decision making tool Laparoscopic Cholecystectomy (LapSkill)	Investigator present: unlimited time review to LapSkill programme on PC and complete modules questions	15 questions on LapSkill per module: 3 Modules on: didactic knowledge of operation, surgical technique, decision-making ability	Immediately after completing programme	No difference in knowledge-based module Experts scored significantly in completion of task and surgical technique modules	Non-randomised Small sample size No baseline test No time limitation for test		None
McQuiston et al.	CEVL paediatric inguinal orchiopexy curriculum (website): comprises 11 component steps Study group (No experience of CEVL curriculum) Control (staff accustomed to CEVL curriculum	Participants study curriculum before performing surgery (self-directed; no time limit Post-surgery: residents and attending mutually archive performance assessment	CEVL skills scores (derived from sum of ratings of each step/skill for max score 55 (11steps/skills at 5 points each) x case difficulty CEVL survey	Immediately after procedure or afterwards (no time specified)	No significant difference in percent who showed an improved learning score in study vs control. No difference in magnitude of average improvement Survey showed positive impact on learning operative progress, improved knowledge of procedure. Component portion specifically helpful	Small sample size Variable times to complete assessment Selection bias Both resident/trainer involving rating skills scores Historical controls – no matched data		None
Sterse Mata et al.	2 Groups: Traditional class: didactic live lecture Self-directed learning: Ebronchoscopy website	2 h training session using website in computer lab or live lecture	20 multiple choice – written assessment	Immediately post intervention	No differences in test scores between the two groups Positive evaluation of Ebronchoscopy	Small sample size. Non-validated assessment tool	High	None

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Table 2 – (*continued*)

Author	Instructional methods	Study format	Method(s) of assessment	Timing of assessment	Summary of main results	Critical appraisal	Risk of bias	Retention test
de Sena et al.	2 groups CAL group multimedia software self-directed application Control group: Text-based print article	5 min of study exposure both groups Followed by 5 min on performance rhomboid flap (training bench model) Control group then exposed to multimedia software for 5 min and reattempted rhomboid flap	Five multiple-choice (MCQ) test OSATS protocol	Pre and post MCQ test immediately before and after intervention OSATs assessment at time of practical	The computer-assisted learning (CAL) group had superior performance as confirmed by checklist scores, overall global assessment and post-test results All participants ranked multimedia method as the best study tool.	Short exposure study time	Low	None
Davis et al.	2 groups/methods: Intervention group: self-directed mobile-learning module (on Apple iTouch) Control group: No instruction	No duration for intervention group stated Participants placed a chest tube on Trauma-Man task simulator	14-item checklist of chest drain insertion used to assess performance	Immediately after instruction or no instruction	Comparing the novice video group with the novice control group, the video group was more likely to correctly perform a finger sweep and clamp the distal end of the chest tube Comparing the expert video group with the expert control group, the video group was more likely to correctly perform finger sweeps, the incision, and clamping the distal chest tube	Non-expert, non-blinded evaluators Non-validated assessment tool		None
C. Pape-Köhler et al.	4 groups/methods: Multimedia-based training Internet platform (www.webope.de) Combination training using with multimedia –based + practical training Practical training No training (control)	Day 1: Baseline pre-test and 2-h training period (all groups) Day 2: Follow-up post-test The tests consisted of laparoscopic cholecystectomy in the Pelvi-Trainer	OSATS protocol	Video recorded Pre-test Day 1, Post-test Day 2 (24hr after)	The OSATS results were highest in the multimedia-based training group Multimedia-based training reached a significantly higher OSATS score compared to participants without multimedia-based training	Selection bias in inviting participants – only those completing questionnaire Small group size	High	None

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Hearty et al.	2 groups: Test group: Residents using textbook + completed e-learning module Control: Residents who used same textbook only E-learning module: Computer Enhanced Visual Learning platform (CEVL) on closed reduction and percutaneous pinning of supracondylar humeral fracture	One week to review textbook, then randomised into groups ?duration of module not stated given All participants followed in an procedure then complete satisfaction survey	60 question test on theory/ methods of the case Satisfaction survey on CEVL module	Post-test ? immediately Test group: access to CEVL then complete test. Control group: complete test (then access to CEVL)	Test group scored significantly higher on the test compared to control group. All participants agreed the CEVL module was a useful adjunct to traditional teaching methods and majority (22/27) agreed module reduced anxiety in the operating room	Lack of control or time on preparation for case ? results influenced by prep work as opposed to module No baseline knowledge pre-test Coin flip randomisation No comment on assessors ? blinded No validated assessment tools Small sample size	None

The 'Cochrane collaboration for assessing risk of bias' was used to assess risk of bias for each study.[21] The risk categories for the included RCT studies were: High risk (7, 50%), Low risk (3, 21%), Unclear (4, 29%).

In the comparative controlled studies, multimedia demonstrated significantly improvement in technical skills performance in 4 studies (2 skill-based, 2 procedural-based studies).[13,20,22,23] In one comparative non-controlled study, multimedia demonstrated significant improvement before and after comparison.[24] In one study, the control group showed significantly improved performance.[25] There was no difference in performance in three other studies (2 skills-based, 1 procedural).[15,19,26] There was one study assessing technical skill performance with no comparative group; this study showed a significant improvement in baseline scores following the use of multimedia.[27]

In three studies, retention tests were performed between 1 and 4 weeks following post-test assessments. In two studies, multimedia platforms demonstrated significant post-retention scores/performance compared to controls.[13,23] The third study did not demonstrate any differences in post-retention scores between groups.[24]

Multimedia demonstrated significantly improved cognitive skill scores in 7 studies (6 RCTs) compared to controls (all procedural-based).[17,20,24,28–31] Significant improvement in scores for the control group was only demonstrated in one study.[13] No differences in scores were demonstrated in three studies (1 skills-based, 2 procedural-based).[32–34] Two studies assessed cognitive skill with no comparative group.[34,35] Improvement in self-assessed knowledge level[34] and significant differences in post-test scores between senior and junior trainees[35] were demonstrated in these studies. There was no retention test performed for cognitive skills.

Evaluation of the multimedia platforms was assessed in 9 studies[17,19,20,25,28–30,33,36] (43%) using survey questionnaires. Results are summarised in Table 2. Overall, evaluation in the 9 studies demonstrated positive results for multimedia platforms.

Discussion

This systematic review focusses on the impact of multimedia platforms for teaching and assessment of surgical skills. There are currently no systematic reviews in the literature focussing on the role of multimedia in surgical training and assessment. Despite heterogeneity of the included studies the following findings emerged:

The majority of multimedia platforms in this review were developed for operative procedures. Of these, the majority (of operative-based platforms) taught and assessed cognitive skills; skills-based platforms tended to assess on technical skills.

In all comparative studies improvements were demonstrated in cognitive and technical skills for both multimedia and conventional teaching. In all non-comparative studies, improvements in both skills sets were also observed.

For both technical and cognitive skills acquisition, the majority of randomised studies demonstrated that multimedia gained significantly improved performance compared

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with conventional teaching. Multimedia and conventional teaching methods were equally effective in six studies (including four RCT studies); three studies assessing cognitive and technical skills each. All groups demonstrated improvement in skill performance. Only two included studies (10%) found that multimedia had a significantly inferior performance compared to conventional teaching.[13,25] Studies evaluating user satisfaction demonstrated a strong acceptance to support use of multimedia.

Why are multimedia platforms having a positive effect on skills training? A person retains only about 10–15% by reading, 10–20% by listening, and 20–30% by what is seen. However, 40–50% of knowledge is retained by presentation of visual and auditory material in an ordered manner.[37] This is the basis of the cognitive theory of multimedia learning (i.e. how people learn from words and pictures).[8,38] Two distinct channels exist in human information processing system – one processing visual information and the other processing auditory information.[8,38] The combination of formats enhances multimedia because multi-sense learning is thought to be superior to didactic teaching.[13]

The steady increase in published multimedia-based studies over the last six years, demonstrates a growing enthusiasm amongst surgical educators and developers. Although initially developed due to budget constraints and declining faculty numbers in undergraduate training of anatomy and basic skills,[13,26] the experience gained enabled the extension of multimedia technology to surgical training and the construction of interactive procedural-based platforms.

Most studies recruited medical students as this was possibly easier than enrolling post-graduate trainees who have clinical commitments. This may account for the smaller group sizes in studies enrolling surgical trainees. However, medical students are a heterogeneous group compared to surgical trainees (due to selection bias and experience). This may have had an effect on the observed differences within studies.[39] The relative paucity of European studies compared to the US may be explained by allocation of funding for educational platforms, with more studies focussed on use of virtual reality simulation.[40]

With rapid development and adoption of virtual reality simulators that have shown to be effective tools for teaching technical skills.[41,42] Multimedia, although effective in basic technical skills acquisition[13,15] is unlikely to play a significant role in teaching and assessment of this skill set. VR simulation, previously accessible only on expensive courses and in a small number of clinical skills laboratories, has started to be implemented into surgical training programmes[43] and will remain an important component of surgical training outside the operating room. The role of multimedia in surgical education would appear more suited to the acquisition of cognitive skills. This is reflected in the greater number of studies focussing on cognitive skills assessment using procedural platforms. This may be because in addition to learning operation steps through text and images, multimedia can provide interactive, engaging visual information whilst simultaneously facilitating spatial orientation.[44]

User evaluation is a constructive and valuable assessment method to determine the educational success of multimedia.[13] High levels of satisfaction suggest that multimedia platforms are being carefully designed by the combination of technology experts and surgical educators.[45] However future studies need to address the developmental process in more detail, including use of software. Future developers and surgical educators need to consider multimedia design principles to ensure future educational success and acceptability.

Overall, the studies reviewed include a diverse range of training procedures and multimedia types, demonstrating applicability in a wide range of disciplines. Multimedia-based surgical procedures, regardless of speciality, appear to be effective. The results of this systematic review demonstrate that both multimedia platforms and traditional teaching methods have a positive effect on surgical skills training. The studies described different learning objectives, teaching methods, intensity of interventions and a wide range of learners, evaluation methods, and measured outcomes. Although heterogeneity of data complicates synthesis of the evidence,[46] the consistency of positive findings reported amongst the studies does point to generalizability, relative feasibility and effectiveness of different multimedia approaches.[46]

This review has a number of limitations. As discussed before, the heterogeneous nature of the evidence base precluded quantitative synthesis of the findings.[47] The studies identified were small in number, and the risk of bias was high in 7 of 14 RCT studies. Therefore, the strength of conclusions relating to validity of findings is limited.[40]

RCT reporting of methodological detail was often not comprehensive; this applied to the method and implementation of randomization (described fully in only 5 (36%) studies). Allocation concealment was only mentioned in 4 studies and blinding of assessors in 8 studies. Sample size and power calculation were only discussed in 5 studies and in general sample sizes were small. Only four RCTs had samples of more than 15 participants per group.

In many studies, there was a lack of valid, reliable assessment tools[48] used to measure primary outcomes. None of the studies assessing cognitive skills used validated assessment tools. This leads to difficulties in assessing the results as poor assessment methods may lead to improper interpretation.[46] Also, the use of identical pre-post/tests (57% of studies) may have contributed to improvement in scores simply by repetition, regardless of the interventions.[49]

All studies focussed on the lower levels of clinical competence[50] and the impact of the educational intervention on patient-centred outcomes is yet to be assessed. The primary outcome measures used can best be considered as a short-term surrogate measure of operative competency, especially in relation to cognitive skills. In addition, the majority of the studies did not include long-term follow-up for retention of skills.[27] Recall ability may diminish over time unless the educational exposure is repeated.[51] Repeat testing, alongside positive feedback, enhances learning and retention of information.[52] There are no major drawbacks to retention tests, and should be encouraged in educational studies.

Further studies are now required to address whether multimedia platforms can actually improve surgical skills

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performance. Studies could initially focus on assessment of intra-operative performance with procedural simulation models or live laparoscopic animal models before introduction into clinical practice.

Other issues include lack of description of costs involved in the design and development of the multimedia platforms. Knowledge of costs and their relative effectiveness enables readers and potential future developers to judge whether these technologies represent practical educational measures. The developmental process of the multimedia platforms was generally poorly discussed in the included studies and needs to be addressed in future research.

Conclusions

This review suggests that multimedia is able to facilitate acquisition of surgical skills in an effective manner, but this may be more suited to cognitive skill acquisition using procedural-based platforms. Multimedia platforms are overall valuable and well accepted educational tools to augment surgical skills training. Further studies are now required to address whether multimedia can actually improve surgical skills performance in the clinical environment.

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